Case Study on Landslide Investigations in Himalayas

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CASE STUDY ON LANDSLIDE INVESTIGATIONS IN HIMALAYAS

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ABSTRACT

The great Himalayan mountains are a majestic cluster of several, more or less parallel, hill ranges intervened by numerous vallies and extended plateaus. At the two ends of Himalayan ranges, other mountain ranges converge. Burmese ranges are in the Eastern and Karakoram-Hindukush mountain ranges in the North-Western end. The individual hill ranges generally present a steep slope towards the plains of India and are more gently inclined towards the north. There are large variations in the geological features of different areas, however, the common phenomena in the landslides occurance is that they are generallly induced by rainfall. In this paper the case history of landslide in limestones at Uttar Pradesh Hill areas and sandstone in Arunachal Pradesh have been presented.

KEYWORDS

Stability of slopes, Trench drains, Mass movements, Tension cracks, Sinking of road, Subsurface drainage, Toe erosion.

INTRODUCTION

The feature of the Himalayan ranges are influenced by the long and continual process of erosion, deposition, uplift and glaciation. The Indian tectonic plate is moving north and eastwards several centimeters each year and therefore the Himalayan ranges lie in a highly seismic zone and is highly earthquake prone. As such, the Himalayan hill ranges are vary fragile and experience frequent landslides. In the present paper a few case histories viz. sinking of road in Landour Cant area, Mussoorie and damage to road due to landslides on National Highway-52A, Arunachal Pradesh are included. These are typical landslide cases, characterising the numerous landslides which occur every year on the hill slopes of the Himalayas. The result of investigations of these landslides, a description of the remedial measures to rectify the slides and the outcome of the monitoring of the sites are described in the following sections CRRI (1994).

INVESTIGATIONS AT LANDOUR CANT

The road stretch leading to some important establishments was damaged due to sinking of slopes after a heavy rainfall. The road stretch was located in a residential area in Mussoorie Cant. The investigations were carried out to understand the cause and mechanism of mass movement and suggest appropriate remedial measures based on investigations to prevent the recurrence of the problem. The remedial measures were aimed at reducing the percolation of water into the slope, modifications in surface drainage and also measures to prevent gulley erosion due to surface runoff. The measures were implemented by the service department concerned and are discussed in detail.

GEOTECHNICAL INVESTIGATIONS

During the field investigations in October 1993, representative soil/rock samples were collected from 5 selected locations in the slide area.These samples were tested in the laboratory for different engineering properties. The grain size distribution curves indicate the soil type to be gravelly sand or silty sand with gravel having more than 20% silt and clay content. The different properties of the soil samples as determined in laboratory are summarised in Table 1. The plan of the affected area, typical section of slope and a view of raod stretch are shown in Fig.1 to 4.

STABILITY ANALYSIS

Based on laboratory investigations, the shear strength parameters $C = 0$ to 15 kPa and $\Phi = 40$ to 43 degree were

Table 1. Typical Engineering Propertiesof Debris Material

Sample No(s)	Natural Moisture (%)	Silt & Clay (%)	Sand (%)`	Gravel (%)	C(kPa)	Φ Degree	Co-effcient of Permeability (cm/s)
S-1	7	7	65	28	0	43	1.2×10^{-3}
S-2	13	4	48	48	-	-	-
S-3	8	4	59	37	-	-	-
S-4	29	21	51	28	15	40	4.22×10^{-4}
S-5	8	7	36	57	-	-	-

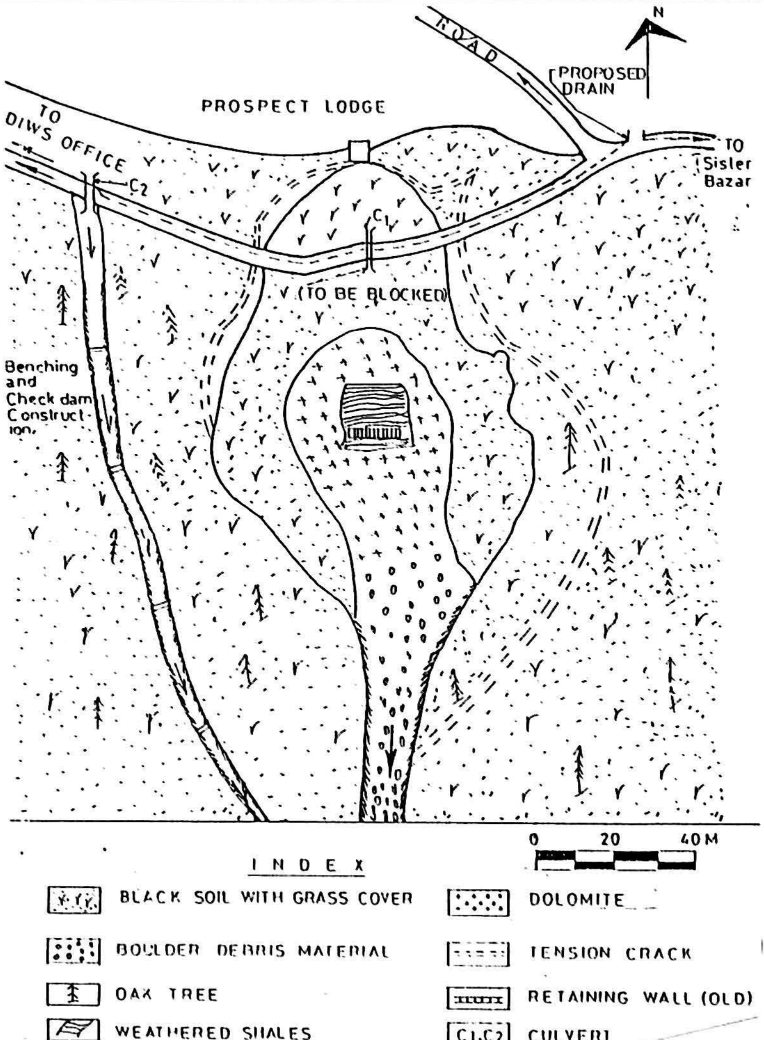

Fig.1. Plan of sinking area affecting the road

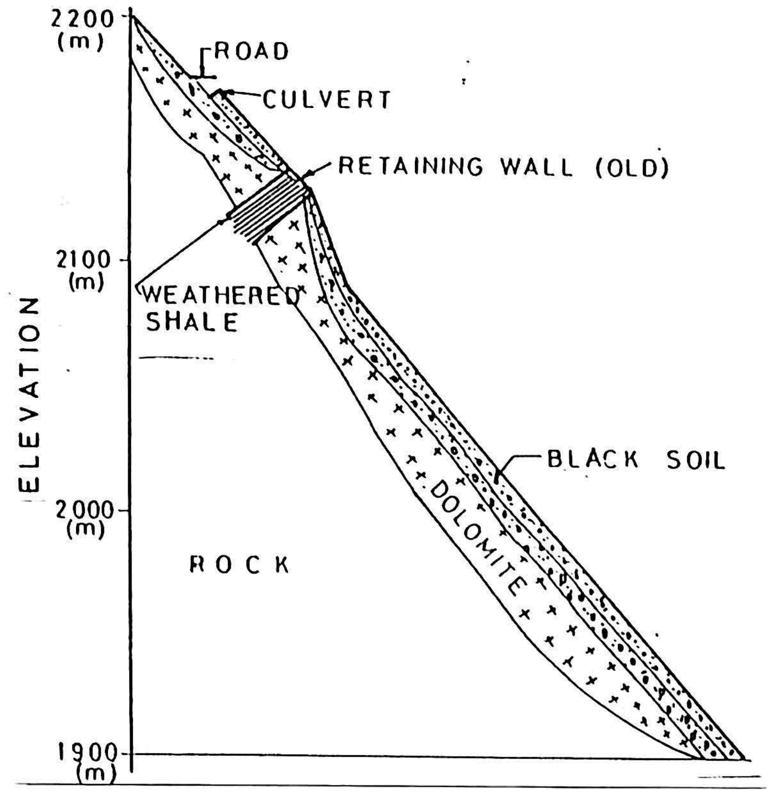

Fig. 2. Typical section of slide affected slope

Fig.3. Photo showing damages at road section

obtained. These values were used for stability analysis. Permeability tests indicated the slope material to be fairly permeable with co-efficient of permeability in the range of 10^{-3} to 10^{-4} cm/s. Stability analysis were carried out using Bishop's method. Table 2 shows the soil parameters used for the stability analysis of the slope.

Analysis using the strength parameters determined in the laboratory i.e. C=10 kPa and Φ=40 degree gives the factor of safety equal to 0.90, indicating the slope to be unstable even without any piezometric line. Field survey had indicated that the main body of the slide area consists of debris and exposed rocks of dolomite, dolomitic lime stone and weathered shale.

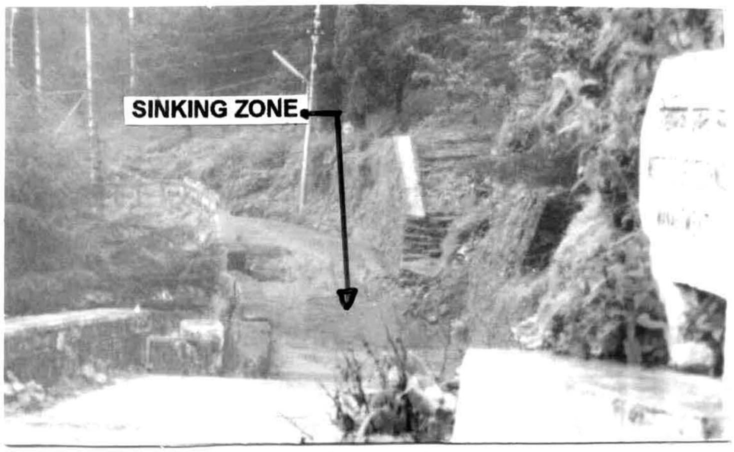

Fig.4. Photo giving general view of sinking zone

Table 2. Parameters Used in Stability Analysis

Parameter	Test Value
Unit weight of slope material	γ= 18.6 kN/m^3
Cohesion	C= x kPa (varying)
Angle of internal friction	Φ= 40 degree
Pore pressure co-efficient	r_u= y (varying)

In other words, the main body of the slide area is a heterogenous mass with shear strength parameters varying from place to place. Accordingly, analysis were carried out for different possible values of available cohesion. Results of stability analysis are given in Table 3.

Table 3. Factor of Safety for Different Values of Available Cohesion, Φ=40 degree

Cohesion C(kPa)	Factor of Safety
0	0.81
10	0.90
20	0.98
30	1.06
40	1.15
50	1.23
60	1.31
70	1.39

Analysis were carried out for different values of Pore Pressure co-efficient r_u. The results are given in Table 4.

Table 4. Variation of Factor of Safety with Pore Pressure Co-efficient r_u, C = 30 kPa Φ = 40 degree

Pore Pressure Co-efficient (r_u)	Factor of Safety	'C' Required for FS = 1.0
0	1.06	30 kPa
0.1	0.85	50 kPa
0.2	0.71	80 kPa
0.3	0.53	-
0.4	0.35	-
0.5	0.14	-

MECHANISM OF FAILURE

The physical evidences show the presence of an old landslide in the area. The percolation of water and subsequent loss of strength lead to movements in the slope mass. The debris slope material, discharge of water into the slide area through culvert located at the crown of slide are some of the main causes of slide.

REMEDIAL MEASURES

To improve the stability of hill slope there was a need to prevent percolation of water into the slope, deterioration of exposed dolomite, dolomitic limestone, clayshales and weathered shales, and to stabilise loose debris material. Suitable steps to reduce surface erosion problem and to improve drainage system to mitigate the effects of extensive flow of rain water were recommended. The same proposals were implemented in the field.

INVESTIGATIONS ON NH-52A

About two kilometers stretch of NH-52A in Arunachal Pradesh was experiencing distresses due to slope stability problem. Field investigations were carried out to determine the causes and suggest measures to keep the highway free from landslide occurrences. The details of investigations, analysis of the causes and the remedial measures implemented at these locations are discussed in this section.

STATEMENT OF THE PROBLEM

The hill slope at the location of the affected stretch comprises of the layers of siltstone and boulder beds of upper Siwalik formation. The top layer being more permeable, results in the excessive percolation of rain water into the slope. In most of the locations the subsurface water was observed to be seeping out at the interface separating the two formation layers viz. the siltstone and boulder bed. At these locations the lower formation layer is denser and has low permeability as compared to the top layer. A number of seepage points leading to gully erosion and formation of rills on the denuded downhill slope were observed. Fig.4 shows the damages to road stretch on National Highway-52A.

GEOLOGY OF THE AREA

The Banderdewa-Itanagar road is aligned through the upper Siwalik formation. The road alignment passes through the formation consisting of interbedded layers of Siwalik boulder beds, siltstones, claystones and sandstones except at a few locations where the stretch is located on the riverine deposit and outwash materials. The brownish and grayish coloured boulder beds and light brown to gray coloured siltstones are exposed on the problematic stretch of the road.

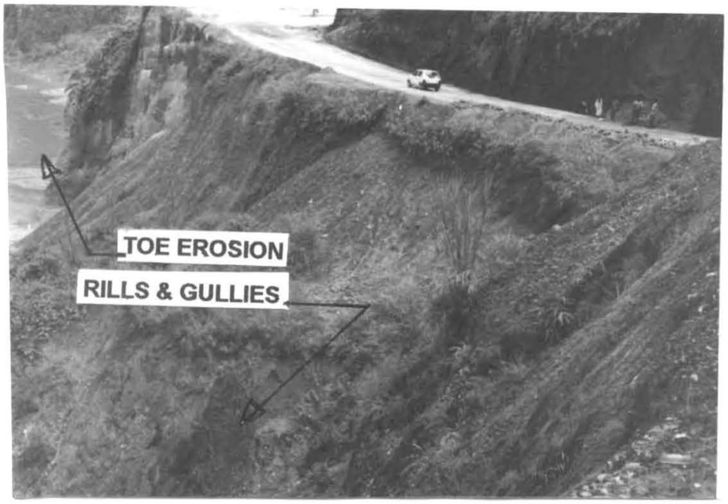

Fig.5 Photo showing damages to road (NH-52A)

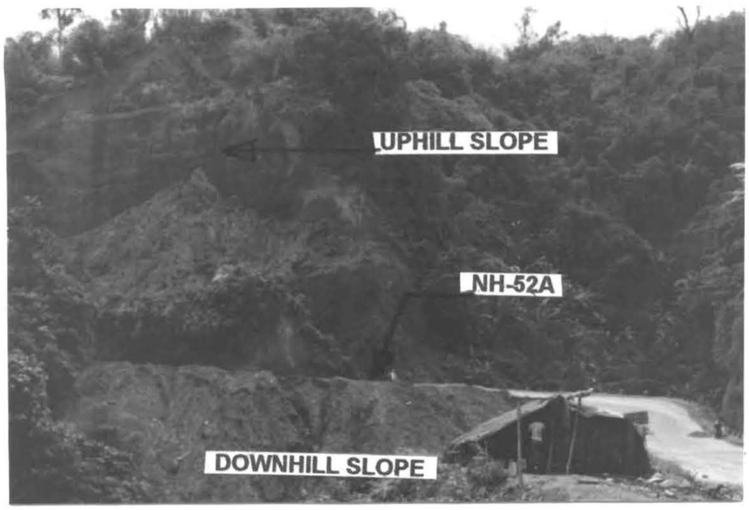

Fig.6. Photo showing landslide on uphill slope (NH-52A)

PRESENT STATE OF SLIDE AREA

The crown of the slide at the affected stretch of the road is situated about 60 to 75m above road level. The crown of the slide has a moderate cover of vegetation. A 3-4m thick layer of soil cover consisting of fine alluvial materials has been observed at the crown portion of the slope. The stretch of National Highway is facing instability problem arising due to number of factors viz. (a) river Dikrong has come dangerously close to the down-hill slope, (b) erosion at the locations of the culverts and two of the culverts discharging onto the affected slope, (c) gulley erosion in the water channels, (d) seepage points causing gulley formation on the downhill slope and (e) erosion due to surface runoff.

FAILURE MECHANISM OF THE SLIDE

The slide area has been experiencing extensive and intensive erosion problems. The main cause of the landslide is toe erosion due to river Dikrong and the seepage of subsurface water into the affected area. The formation on downhill slope is affected by erosion and denudation. Numerous seepage points all along the downhill slope and the culverts discharging onto the downhill slope, result in the loss of slope material and also the formation of numerous rills and gullies due to surface runoff.

The sliding process is accentuated by the rains and subsurface water which seeps out at a number of places through the contact of boulder bed (permeable strata) and underlying fine grained siltstone layer (impermeable strata). At a number of points in the affected stretch, water from underground springs and channels migrating towards the slope through gullies, still enriches the degree of saturation of slope material. During rainy season these streams not only saturate the slope material but also cause erosion.

REMEDIAL MEASURES

To reduce the impact of river water at the toe and stabilise the downhill slope by constructing a toe wall all along the affected stretch in wire/synthetic crates.

To divert the flow of river away from the hill side slope, by constructing a series of spurs located at appropriate distances.

To construct rubble drains at the locations of seepage points in the downhill slope. A geotextile layer may be used around the drains which will act as a filter preventing the migration of slope material.

To diverted water away from the affected stretch.

To promote vegetation on the downhill slope and the fresh cut or fill slopes using jute/coir geogrids.

On the basis of stability analysis it was suggested that the affected slope should be restructured to make flatter using benching technique and to restore down hill slope.

ACKNOWLEDGEMENTS

Thanks are due to scientists and other staff members of CRRI involved in the investigations of above landslides.

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